Cancer and Suicide Near Asphalt Distribution Facilities: Salisbury, North Carolina
A Report of a Six-Year Investigation

Douglas Campbell, MD, MPH
Occupational and Environmental Epidemiology Branch
North Carolina Division of Public Health
April 17, 2006

EXECUTIVE SUMMARY:

1. The number of cases of brain cancer and lymphoma in a one and two-mile distance from the asphalt distribution terminal and associated industrial facilities on Jake Alexander Boulevard in Salisbury, North Carolina, from 1990-2003 are not significantly different from what would normally be expected. This has been shown in seven studies by the North Carolina State Center for Health Statistics (SCHS) and a study by the federal Agency for Toxic Substances and Disease Registry (ATSDR).
2. A study by the SCHS of twelve asphalt distribution terminals in North Carolina shows that the number of cases of cancer within a one-mile and two-mile radius from these facilities was not significantly elevated. Because this study utilized a large study population, it has a greater power to discover an increased risk between asphalt plant emissions and cancer if one exists, compared to studies of a much smaller population around the Salisbury asphalt distribution terminal.
3. A study performed by the ATSDR determined that the numbers of cases of brain cancer and lymphoma were "statistically significantly elevated" in two census block groups of Milford Hills. However, these two census block groups have very small numbers of residents and the number of cancers is small. Due to the small numbers and unstable rates, no scientifically defensible association between the proximity of the asphalt plant to Milford Hills and cancer in residents of Milford Hills can be made and it cannot be concluded that contaminants from the asphalt facilities caused cancers or suicide.
4. A study by the SCHS of eleven asphalt distribution terminals in North Carolina shows that the rate of suicide within two miles of these terminals was actually less than the rate in the remainder of the state, suggesting that living within two miles of asphalt distribution terminals is not a risk for suicide.
5. A study by the SCHS of two census block groups in Milford Hills showed that there had been six suicides in this area in the ten-year period between 1994 and 2003. While this was greater than expected in this area, it was the opinion of the SCHS that this low number of suicides made statistical analysis unstable. The occurrence pattern of suicides during that time was not consistent with a hypothesis that air pollutants from the asphalt distribution facility were responsible for the suicides.
6. Statistical significance does not imply causation. The use of statistical tests of incidence rates to determine if numbers or rates of cancers or suicides are elevated in a given geographic area cannot be used to imply or determine that a given environmental risk factor is responsible for the increased rates.
7. The studies of cancer incidence performed in the studies of Milford Hills are only designed to determine numbers or rates of new cases. The incidence data do not have any information on any individual risk factors for cancer or suicide so these incidence data cannot be used to support any proposed causal associations. Individual risk

Comment [E1]: Over what time period?

Comment [E2]: ? determined

factor data that are missing include duration of living in Milford Hills, family history of cancer or any genetic information, dietary history, exposure to occupational risk factors, medical history, exposure to ionizing radiation, or any specific environmental exposures. Missing risk factors for suicide include all of those listed on pages 9 and 10 of this report.

8. Hydrogen sulfide was found in Milford Hills at levels that gave a disagreeable odor. Other chemicals measured in the air of Milford Hills have been found in similar concentrations in other rural and suburban settings.
9. There were no chemicals measured in the air or water of Milford Hills that are known as human risk factors for brain cancer, lymphoma or suicide. Hydrogen sulfide has not been shown to be a risk factor for suicide.
10. No investigation of the suicide cases in Milford Hills has been done to determine the presence of established and accepted risk factors for suicide in those persons prior to the suicides. Because of the many known and established risk factors for suicide, it is not plausible to postulate that the suicides were caused by environmental factors which have never been causally linked with suicide before determining the presence or absence of established, non-environmental risk factors for suicide.
11. Exposure factors and health outcomes must be systematically evaluated in order to determine if the factors "cause" the outcomes. When environmental exposures in Milford Hills were considered in the context of the Bradford-Hill criteria (pages 10-12), there was no support for a hypothesis that environmental contaminants caused brain cancer, lymphoma or suicide in the Milford Hills area.
12. It is the opinion of the Occupational and Environmental Epidemiology Branch (OEEB) that a more in-depth epidemiologic study should not be undertaken. If a more in-depth epidemiological investigation were to be proposed, one needs to consider that it is not possible to accurately determine levels of exposure to any past environmental agents as well as many other personal risk factors. Therefore, the role of causality in any associations suggested by a retrospective (based on data from the past) epidemiologic study would be speculative at best. In addition, the very small number of cases of cancer in Milford Hills would not be sufficiently large to establish a statistically significant association between any exposure variable and disease.
13. There has been significant improvement in the ambient air in Milford Hills and other areas around the asphalt distribution terminal since placement of activated carbon filters on the asphalt storage tanks in March 2002. The number of telephone calls for odor complaints has noticeably decreased since placement of the filters.
14. Municipal public water has been provided to residents of Milford Hills, thus eliminating any potential risk factors in drinking water that are associated with past groundwater contamination.
15. Based on the results of the air sampling performed in 2001, the opinion of OEEB is that the ambient air near the asphalt treatment facility in Salisbury posed an intermittent odor problem and may have caused respiratory tract irritation prior to installing activated carbon filters, but that even before placement of the filters the low concentrations of measured pollutants in the ambient air near the facility and in Milford Hills did not pose a risk of causing brain cancer, lymphoma, or suicide.
16. It is the opinion of OEEB that appropriate public health measures have been taken to respond to the air and water contaminants in Milford Hills.

Comment [E3]: Has it been linked with exposure to higher concentrations of H2S or VOCs ---other than high occupational exposures to carbon disulfide in rayon plants in Italy?

Comment [E4]: This begs the question, why was this not done on such a small number of cases—review of medical records. Your answer should be that we plan to do that?

Comment [E5]: What about suicide?

Cancer and Suicide Near Asphalt Distribution Facilities: Salisbury, North Carolina
A Report of a Six-Year Investigation

Occupational and Environmental Epidemiology Branch
North Carolina Division of Public Health
April 17, 2006

Introduction:

Since the year 2000 a former resident of the Milford Hills area of Salisbury, North Carolina, has voiced concerns that there have been an unusually large number of persons diagnosed with cancer in this neighborhood. This resident also has voiced concerns that an unusually large number of persons in Salisbury have committed suicide in the past few years. The resident has postulated that the large number of cancer and suicide cases may have been causally related to contamination of air and groundwater by chemicals thought to have originated from Associated Asphalt, an asphalt distribution terminal located at 1825 Jake Alexander Boulevard in Salisbury, and associated industrial facilities, as well as groundwater contamination from the former Exxon terminal and the Southern States Cooperative. All of these concerns led North Carolina and federal public health and environmental officials to conduct an extensive, six-year, multi-agency investigation, which included an in-depth statistical investigation of the situation in Milford Hills and in Salisbury. During the course of these studies, several changes in the asphalt facilities were made in order to improve air quality, and public water was made available to residents of Milford Hills.

Comment [E6]: Postulated? erroneously concluded?

Salisbury, North Carolina, is a city with a population of approximately 25,440 persons located in Rowan County, in central North Carolina. The Associated Asphalt facility is located on Jake Alexander Boulevard in Salisbury. Milford Hills is a residential subdivision that is located just north and northeast of Jake Alexander Boulevard. Much of Milford Hills is located within two miles of the Associated Asphalt facility.

The following report summarizes what has been learned and accomplished in the course of this six-year investigation. This report also makes public health conclusions and recommendations regarding the concerns about high numbers of cancer and suicide cases, and their possible relation to environmental contaminants originating at Associated Asphalt and it's associated industrial facilities, and to environmental contaminants in general. This report will address three questions:

1. What has been done to investigate and respond to the possible health problems of concern in Milford Hills and in Salisbury?
2. Can cancer and suicide in Milford Hills and Salisbury be causally related to environmental contaminants originating at Associated Asphalt and associated industrial facilities?
3. Should anything further be done to investigate or respond to these concerns about these health problems in Milford Hills and Salisbury?

1. What has been done to investigate and respond to the possible health problems of concern in Milford Hills and Salisbury?

Studies of cancer incidence, suicide, and environmental evaluations are described in more detail in Appendices 1 through 3 on pages 15-28 of this report.

A. Cancer:

The Central Cancer Registry (CCR), which is part of the North Carolina State Center for Health Statistics (SCHS), has performed several studies of the incidence (new cases) of cancer in Salisbury and other parts of North Carolina. The North Carolina Department of Environment and Natural Resources (DENR) has performed an environmental investigation of the area in and around the asphalt terminal facility in Salisbury and has been instrumental in taking steps to improve the air quality near the asphalt facility. The federal Agency for Toxic Substances and Disease Registry (ATSDR) has performed a study of the incident cancer cases around the Asphalt facility and has recently submitted its report. The Occupational and Environmental Epidemiology Branch (OEEB) of the North Carolina Division of Public Health has been involved in evaluating the above efforts and responding to county officials in Salisbury since 2000.

Comment [E7]: What is meant by an environmental investigation of Salisbury

Comment [E8]: ? near

The CCR was established in North Carolina in 1986. At that time North Carolina required that all cases of newly diagnosed cancer be reported to the CCR so that there would be information available about the number of incident cases of all cancers in persons with a residence address in North Carolina at the time of the report. Reliable incidence data has been available since 1990. The studies of cancer done for this investigation were based on incident (new) cancer cases reported to the CCR since 1990. Information on each reported type/site-specific cancer case includes identifying demographic data such as age and sex, but does not include information about potential risk factors for that cancer. Because of the available information on each case, the CCR data are not designed to give information about causal factors of cancer, but only information about how many cases of type-specific cancer were diagnosed in North Carolina on a specific date. It is important to remember that none of these studies are capable of determining the possible cause(s) of the cancer in a given geographic area over a given time period. However, they can determine whether or not the number of type/site specific cancer cases in a given geographical area are statistically significantly different compared to other surrounding areas (e.g. compared to other census tracts, or the county or state as a whole). In order to justify further investigation, the presence of increased rates (meeting statistical significance) and other factors supporting a significant statistical result must first be met.

In the CCR studies, no evidence of a significantly increased incidence of cancer was found within either a one or two-mile radius of the asphalt facility. In other words, the number of incident cases of cancer since 1990 within both a one-mile radius and within a two-mile radius of the asphalt plant were not significantly greater than would normally be

Comment [E9]: Nonsensical statement at least to me—what does this mean?

expected. The study by ATSDR confirmed this finding when incident cases were evaluated within one mile of the asphalt facilities. The ATSDR did not evaluate cases in a two-mile radius of the asphalt distribution facility. Because of concerns voiced by the past resident of Milford Hills, ATSDR evaluated a smaller part of the past population within one mile of the industrial facilities. ATSDR found that the number of incident cases of brain cancer and lymphomas was statistically significantly greater than expected in two census block groups (0513031 and 0513032) within one mile of the asphalt distribution terminal. The ATSDR notes, however, that the small number of cases and the lack of any information about possible risk factors and chemicals exposures weaken any observed statistically significant increase. ATSDR also notes that the results of their study cannot explain how or why these rates may have been elevated. The ATSDR concludes that "...ATSDR cannot establish any causal relationship between these elevated rates and any contaminant in the test area." It must be remembered in all of these studies that statistical significance does not imply causality in the context of these studies.

Comment [E10]: What about 2 miles did they look at that or not, if not clarify statement.

Comment [E11]: Confused here ATSDR evaluated new cases and confirmed no increased rate and then evaluation pop within one mile and found increased rate.

Comment [E12]: (do you mean the asphalt facility/ies near Milford Hills

Comment [E13]: Which two ? / Milford Hills

Comment [E14]: Not worded clearly

B. Suicide:

In summary, the study of suicide performed by the SCHS determined the following:

1) The rate of suicide in persons living within two miles of a group of eleven asphalt terminals in North Carolina was less than the rate of suicides in the remainder of North Carolina, suggesting that living within two miles of an asphalt distribution terminal is not a risk factor for suicide

2 When the number of suicides was determined between 1994 and 2003 within two census block groups in Milford Hills that were within one mile of the asphalt distribution terminal on Jake Alexander Blvd, the number of suicide cases was significantly greater than would be expected. However, this is based on six suicides in 12 years. This number is very small and is not stable statistically. The number of suicide cases in these two census block groups varied widely over the ten year period. There was one suicide in 1994 and two suicides in 1995. There were no suicides for the five-year period from 1996 until 2000. During this time there were no effective controls on emissions from the asphalt distribution terminal on Jake Alexander Blvd. There was one suicide in 2001. Activated carbon filters were placed on asphalt storage tanks in March 2002 with significantly diminished odor complaints after that time. There were no suicides in 2002 and there were two suicides in 2003, after odors and odor complaints had significantly decreased.

Comment [E15]: Why two different tests and which test is more appropriate. Was it significant or not. I would get SCHS to review the sections related to what they did.

If there were a causal association between hydrogen sulfide levels in the air and suicides, one would expect increased numbers of suicides during years in which the emission of hydrogen sulfide and odors were greater, not the reverse.

C. Environmental evaluations:

Comment [E16]: Get Bill Pate and Langley to go over this with a fine tooth comb but ask Bill to do the editing.

The North Carolina Department of Environment and Natural Resources (DENR) performed air monitoring at three sampling sites around the Associated Asphalt facility in May through September 2001. Appendix 3 on page 23 lists results of these air studies. The results of groundwater samples evaluated by the North Carolina Groundwater Section of DENR in Milford Hills and in the area of the asphalt distribution facilities from 1992 through 2005 were used to determine the presence of groundwater contaminants. The results of these samples are given in Appendix 3.

1) Air monitoring: See Appendix 3 for air monitoring results.

DENR notes that hydrogen sulfide was the chemical emitted in the greatest concentration from the asphalt distribution facilities. Volatile Organic Compounds (VOC's) were also found in air sampling performed by DENR. Both hydrogen sulfide and VOC's were found at elevated concentrations in and at the boundary of the asphalt distribution facilities but the levels of these contaminants decreased significantly in samples taken in sampling sites off-site from the asphalt facilities. Hydrogen sulfide levels no greater than 50 parts per billion (ppb) were found in monitoring sites away from the asphalt facilities. The great majority of measured concentrations of hydrogen sulfide in and adjacent to Milford Hills were no greater than 30 ppb. VOC's were also elevated at the asphalt facility, but DENR notes that levels of VOC's measured in sampling sites in Milford Hills were similar to levels of these chemicals found in other rural and urban settings in North Carolina and nearby states.

Hydrogen sulfide is a gas with a characteristic, unpleasant "rotten egg" odor. Its odor is detectable at concentrations as low as 1-8 ppb and is termed a "nuisance" at 40 ppb. It can irritate the mucous membranes of the eyes and respiratory tract, and may increase symptoms in persons with asthma at 24-hour average concentrations as low as 50 ppb. It can be fatal at concentrations over 500 ppm. It should be noted that hydrogen sulfide is not a known carcinogen and is therefore not a known risk factor for either brain cancer or lymphoma. It has never been demonstrated in the scientific literature to be an established risk factor for suicide.

Based on the above discussion of the chemicals found in the air of Salisbury and the Milford Hills area, it is the opinion of OEEB that hydrogen sulfide was present at levels that could be smelled and were unpleasant and may have contributed to worsening of symptoms in asthmatics and irritation of mucous membranes. However, OEEB does not expect any long-term or chronic health effects from these levels of hydrogen sulfide. Since hydrogen sulfide is not a carcinogen, it is the opinion of OEEB that no cancers resulted from exposure to hydrogen sulfide in Milford Hills.

Concentrations of all other chemical contaminants in the Milford Hills area were similar to concentrations found in normal urban settings in and around North Carolina. Our search of the medical literature has shown that no chemicals detected by air monitoring studies in the Milford Hills area have been found to be risk factors for either brain cancer or lymphoma at levels measured in the Milford Hills area.

2) Groundwater monitoring: See Appendix 3 for results of groundwater sampling.

Representatives of the Division of Water Quality (DWQ) in DENR have determined that the direction of ground water flow from the asphalt facilities was away from the Milford Hills area. As a result, contaminants present in the Jake Alexander Blvd samples would not migrate to Milford Hills. Some of the contaminants found in the samples from the Jake Alexander address did not appear in the samples from the Milford Hills area. None of the contaminants found in the groundwater from the Milford Hills area are known causes of brain cancer or lymphoma.

3) Remediation of sources of air emissions:

Odor complaints in the Milford Hills area were recorded since the first complaint on March 11, 1999. From that date until July 15, 2004 there was a total of 566 odor complaints. Following the air monitoring studies by DENR in 2001 it was determined that hydrogen sulfide was intermittently present in concentrations greater than the odor threshold in the Milford Hills area. To remediate the primary source of hydrogen sulfide fumes, activated carbon filters were placed on asphalt storage tanks at the Associated Asphalt facility in March 2002. Following this step the number of odor complaints from Milford Hills decreased significantly.

"Air sparging" (a process of pumping air through groundwater and venting it to the atmosphere at ground level) was being performed to decrease contamination of the groundwater and there were concerns that this process was releasing VOC's into the air near Milford Hills. This process was terminated in March 2002.

4) Remediation of groundwater contamination:

Beginning in the early 1990's the city of Salisbury provided municipal water to residents of the Jake Alexander Blvd area and Milford Hills who had previously been using groundwater. It is the understanding of OEEB that most of the Milford Hills residents have switched from private wells (groundwater) to municipal water as of the date of this report. The exact number and percentage is not known by the OEEB.

2. Can cancer and suicide in Milford Hills and Salisbury be causally related to environmental contaminants originating at Associated Asphalt?

Background:

A. Cancer:

1.) What is known about the cause of cancer?

Cancer is a common group of illnesses occurring in up to one of two males and one of three females in their lifetime. Because it is a very common illness, it is expected that any community will have many people with a history of cancer. It is not uncommon for people to talk to other people in their neighborhood and be alarmed about the number of cancers because cancer is common and is such a frightening disease.

Cancer is the end result of many risk and causal factors. A combination of genetic, environmental, and life-style factors are known contributors to the incidence of cancer, often in ways that are not understood. While we know risk factors and causal factors for many cancers, we do not know these for all cancers. For example, we know that tobacco smoking is a strong risk factor for more than 80% of lung cancers, asbestos exposure is strongly related to mesothelioma of the lining of the lung, human papilloma virus is related to cervical cancer, Hepatitis B virus is a risk factor for liver cancer, and sun exposure is strongly related to many skin cancers. In some cancers environmental risk factors act together to increase the risk of cancer. For example, smoking and asbestos exposure together greatly increase the risk of lung cancer.

These examples show that an environmental exposure can be one factor in the development of cancer. However, the "environment" is a complex mixture of factors to which everyone is susceptible, including air, water, soil, home, workplace, diet, tobacco products, alcohol, drugs, chemicals, infectious agents, sunlight, ionizing radiation from medical procedures and from the environment, and other forms of radiation. Exposures to environmental factors can occur for varying lengths of time, and these factors can interact in ways that are not yet fully understood. Individuals have different susceptibilities to these factors. Even in similar environments every individual has a unique set of environmental exposures that may affect their risk for cancer.

It is often difficult to isolate one environmental factor above others that will determine if someone will develop cancer. Most cancers cannot be explained by single, identifiable environmental exposures, but are the result of a chain of events occurring over a period of time. For example, genetic factors and environmental exposures often interact in ways that lead to cancer, but the character of these interactions is often unknown. It is very difficult to go back in time to recreate an environmental exposure with any certainty. Since everyone's environmental experience is different, it is usually not possible to ascribe a cancer to a single environmental exposure except in instances where exposure to an environmental factor meets stringent epidemiological criteria.

2.) Brain cancer and lymphoma

Brain cancer is the most common solid tumor in children and is the second most common malignancy (cancer) of childhood. Brain/CNS cancer ranked nineteenth in frequency in North Carolina in 2003. Lymphoma is a malignancy of the lymphatic system. It is the fifth most common malignancy in adults and the third most common malignancy of children.

There are many specific histological tissue types of both brain cancer and lymphoma, each with unique frequencies of age and sex in persons with that specific tissue type of cancer. The ultimate cause(s) of brain cancer and lymphoma are not known, but research has shown several factors to be associated with an elevated risk of developing these cancers. The exact role of these risk factors is not known. Each specific tissue type of these cancers likely has its own constellation of risk factors and causal factors, including genetic traits. The CCR found that a breakdown of the tissue types of cancer was as follows:

In one-mile distance: 6 brain cancer cases with 5 different histological types
7 lymphoma cases with 5 different histological types
In two-mile distance: 11 brain cancer cases with 6 different histological types
27 lymphoma cases with 14 different histological types

Brain cancer: the following risk factors have been identified for brain cancer in general:

- Known: Sex (males greater than females), genetic factors, exposure to ionizing radiation
- Suggestive but not conclusive evidence: family history of either bone cancer, leukemia or lymphoma; parents/sibling with brain cancer
- Limited or inconsistent evidence: family history of epilepsy or mental retardation; history of head injury; father's occupation; exposure to electromagnetic radiation, consumption of foods containing N-Nitroso compounds; exposure to pesticides

Lymphoma: The only known environmental risk factor for lymphoma is the Ebstein-Barr Virus (EBV) that is a strong risk factor for Burkitt's Lymphoma in Africa. There is some evidence for the following factors that may increase the risk for the development of lymphoma:

Suggestive: genetic; exposure to non-arsenical pesticides, TCDD (a dioxin), tetrachloroethylene, trichloroethylene, viruses (EBV as noted above)

It should be noted that no chemicals that were identified in air emissions in Milford Hills from the asphalt distribution terminal on Jake Alexander Blvd or in the groundwater samples from the Milford Hills area have been shown to be risk factors for either brain cancer or lymphoma.

Low levels of trichloroethylene were measured in groundwater at Jake Alexander Blvd but no trichloroethylene or tetrachloroethylene was measured in groundwater in Milford Hills. Animal studies have suggested a possible role of tetrachloroethylene and trichloroethylene in liver and kidney cancer. Human data are not adequate to term it a carcinogen. No animal studies show that trichloroethylene has been associated with brain cancer. Since the Groundwater Section has noted that groundwater from the asphalt facilities migrates in a direction away from Milford Hills, contaminants present in the groundwater from the location of the asphalt facilities on Jake Alexander Blvd would not pose a risk for Milford Hills.

B. Suicide:

1.) Risk factors for suicide:
Previous suicide attempts
Depression or other psychiatric problem
History of treatment for psychiatric problem
Psychotic features- especially hallucinations
Substance abuse
Positive family history of suicide
Loss or stressful life event
Living alone and/or social isolation
Low levels of social integration in a community
Age: young people are at risk, risk also increases with age; in males risk peaks at age 75; in females risk peaks from 55-65
Marital status- single or divorced at higher risk than married
Employment: unemployed at greater risk than employed, unskilled greater risk than skilled
Low socioeconomic standing
Physical illness: 50% of all patients who attempt suicide have a physical illness; at greatest risk are those persons with chronic pain

It should be noted that no studies were found in the medical literature that demonstrate that exposure to hydrogen sulfide or any other chemical found in the environmental testing of air or water of Milford Hills is a risk factor for suicide.

C. Causality in environmental studies:

In the field of environmental epidemiology it is usually difficult to prove that an environmental factor causes a health outcome. In order to "prove" a causal association it is helpful to assess a situation in an organized manner by evaluating the situation methodically and with a predetermined set of standards or criteria. A commonly used set of standards or criteria was proposed by Sir Austin Bradford Hill in 1965. There is no specific formula for how many of these criteria must be met to suggest causality, but the more of them that can be met suggests that causality is more likely and the fewer of them that are met means that causality is less likely. Meeting the criteria does not prove causality, and some of the criteria are controversial, but it is useful to examine the situation in Milford Hills in the context of these criteria. The criteria proposed by Hill are:

1.) Strength of association
2.) Consistency of findings
3.) Specificity of findings
4.) Temporality of findings
5.) Biologic gradient
6.) Plausibility
7.) Coherence of findings

8.) Experimental Evidence
9.) Analogy

1.) Strength of Association:
Hill argued that strong associations are more likely to be causal than weak associations. As seen in section I, CCR and ATSDR both showed that there were no statistically significant elevated rates or numbers of cases of cancer or suicide within either a one-mile or two-mile radius from the asphalt distribution terminal on Jake Alexander Blvd. When cancer rates and suicide rates were examined within one and two miles of a group of asphalt distribution facilities in North Carolina there were no statistically significant elevated rates or numbers of cases of cancer. These multi-site studies evaluate a larger population and have greater power to detect a significant difference of rates if one exists. The ATSDR study of a small part of the Milford Hills area showed significant elevations of brain cancer and lymphoma in two census block groups, but this is with very small numbers and statistical significance is unstable in those situations. None of the other statistical studies of cancer showed statistically significant numbers or rates of illness.

2.) Consistency of findings:
This refers to the repeated observation of an association in different populations under different circumstances. As seen in section I, eight studies by the SCHS, the CCR, and the ATSDR that showed there to be no statistically significant excess number of cases or rates of cancer or suicide in a one and two mile radius around the Jake Alexander Blvd facility as well as in studies of a larger group of asphalt distribution terminals throughout North Carolina.

3.) Specificity
This criterion requires that a cause lead to a single effect, not multiple effects. This criterion is controversial since one cause can have different effects so requiring a cause to have only one effect is not necessarily required for causation. As a result this criterion will not be addressed in this analysis.

4.) Temporality of findings
This refers to the necessity that the cause precedes the effect in time.
None of the measured contaminants in air or water of Milford Hills is a known carcinogen or cause of suicide so exposure to them should not result in a later cancer or suicide. Additionally, we don't know any individual's personal exposures to any environmental factor in the past so we cannot use temporality for nearly all exposures. Two out of the six suicides in Milford Hills occurred after air emissions had been noticeably improved and exposures were noticeably decreased. There were no suicides during a six-year period when effective air emission controls were not in place and levels of hydrogen sulfide were higher. Both of these outcomes are the opposite of what would be expected for cause to precede effect.

5.) Biologic gradient
This refers to the expectation that more cancers or suicides should occur with exposure to higher levels of environmental contaminants.

All of the CCR studies showed that numbers of cases of cancer at one and two miles from the distribution facilities were not statistically significantly elevated compared to numbers of cases in the rest of the state. This was confirmed by the ATSDR study, which showed no greater numbers within one mile, compared to what would be expected in Rowan County.
The SCHS study of suicides shows that the rate of suicides within two miles of eleven asphalt plants was lower than the rate in the rest of the state. This is the opposite of a positive "biologic gradient."

6.) Plausibility

This refers to the biologic plausibility of a hypothesis that an exposure causes an outcome.
Since no scientific studies of the contaminants found in the air or water in Milford Hills have shown them be causes of brain cancer, lymphoma, or suicide, it is not plausible to suggest that exposure to these contaminants caused any of these three outcomes.
Since the chemical contaminants measured in air in and adjacent to Milford Hills were found at levels similar to those found in many other urban and rural settings, it is not plausible to assert that they are responsible for a noticeably increased incidence of cancer in this one community.
Persons in Milford Hills have many unique personal risk factors and are exposed to many environmental factors besides contaminants in neighborhood air and past groundwater. It is not plausible to suggest that these two environmental factors are responsible for cancer or suicide when no other personal risk factors have ever been evaluated.

7.) Coherence of findings

Coherence implies that a cause-and-effect interpretation for an association does not conflict with what is known about the natural history and biology of the disease.
This is discussed in 6. above.

8.) Experimental Evidence

Since neither animal nor human studies have demonstrated that contaminants measured in air and water of Milford Hills are causes of brain cancer, lymphoma or suicide it is not logical to propose that cancers and suicides in Milford Hills are caused by exposure to these contaminants. It is not logical to propose that exposure to chemicals that do not cause brain cancer, lymphoma, or suicide caused a significant community-wide cluster of these health outcomes.

9.) Analogy

This criterion is also controversial and will not be discussed here.

D. Cluster analysis as a method of determining a causal association between environmental factors and either cancer or suicide:

"Cluster studies" have historically been performed to evaluate risk factors for cancer and other illnesses. Historically these have been done by the Centers for Disease Control Prevention and state departments of health, but they have fallen out of favor because they

so rarely provide any useful evidence to determine causal factors for cancer. The following is a description of this type of study with specific reference to North Carolina, and some of the weaknesses of this type of study:

When concern arises that there are more than the "normal" or "expected" number of cancers in a neighborhood and an evaluation is undertaken, the evaluation proceeds in stages. The first stage is to determine the number of cases of a specific tissue diagnosis. With this information an evaluation can be performed to compare the number of cases of cancer that are found in an area to the number that are expected in that area. In North Carolina this evaluation is performed by the North Carolina CCR. In studying incidence rates of cancer it is important to account for the age distribution in an area being studied since age is a risk determinant for many cancers. This process is known as "age adjustment."

The study of incidence rates in North Carolina as described above has many limitations that make it impossible to evaluate most if not all risk factors and ultimate causes of cancer. Although the CCR does have data available on age and sex of a cancer case, there are no individual-level data provided by the reporting agency to CCR on risk factors for development of cancer. Demographic, lifestyle, and family risk factor data that are not available include duration of residence at the site noted on the laboratory report when cancer is diagnosed, potential exposures to carcinogens associated with occupation and avocation, tobacco usage, diet, medication usage, exposure to radiation, family history of cancer, or any other exposures that might contribute to the development of cancer. Because of the limitations noted above, a study of incidence rates alone cannot show what might have caused any of the cancers. If the rates are dramatically high for a specific tissue type of cancer, such as medulloblastoma, a specific tissue type of brain cancer, then consideration is given to pursuing a more in-depth study. However, before consideration is given to pursuing a more in-depth study the following factors must be considered for all cluster studies:

1.) Area and Time Period: The area and time period for a cluster study is usually arbitrary. This arbitrary choice of a study area and time period will influence the likelihood that a specific exposure or location is shown to have an association with the cancer.
2.) Size of Population: If the population of a study area is small then very small changes in numbers of cancer cases can dramatically affect the rates. For this reason it is desirable to study a reasonably large area. In the studies done in Salisbury and other places, rates in a small area such as a census block group are statistically "unstable" and can change dramatically with small numbers of new cases. As a result it is not realistic to draw conclusions from any statistical significance tests performed on those small areas since the occurrence of even one additional case can dramatically affect the rate.
3.) Exposure Information: It is not possible to get accurate exposure information for past events since they are rarely, if ever, measured. Most exposure determinations in cancer studies are rough estimates. This is even true in the occupational setting. It is not possible to go back several years and re-create

with any certainty a person's water, air, dietary or other exposures. If it is alleged that an environmental exposure was the cause of a cancer and that exposure cannot be measured or accurately estimated then it will not be possible to determine any epidemiological proof of causation.

For these reasons and others it is not possible to perform an epidemiologic study of cancer that will have the ability to reliably show likely environmental causes of cancer.

In the case of suicide it is necessary to interview friends or relatives of the victim so that obtaining reliable information as to possible causes of the suicide is exceedingly difficult. If there is concern that an environmental exposure is responsible for a suicide then it must be remembered that it is virtually impossible to go back in time to accurately determine a persons exposures to any environmental factors prior to the suicide.

Because of these limitations, cluster investigations of cancer and suicide are rarely done to determine environmental causes. If they are done then it must be acknowledged prior to starting the study that definitive results are not possible in virtually all cases. The high cost in dollars and person-hours will not be fruitful in determining the exact cause of the cancer or suicide.

3. Should anything further be done to investigate or respond to the health problems described in this report in Milford Hills and Salisbury?

This six-year effort by North Carolina and federal officials has resulted in placement of activated carbon filters in storage tanks at the asphalt distribution terminals and noticeably improved air in the Milford Hills neighborhood. Municipal water has been provided to the Milford Hills residents. No chemical contaminants identified in the air or water in the Milford Hills neighborhood have been definitively shown to be associated with brain cancer, lymphoma or suicide. The number of incident cancer cases in a one and two-mile distance from the industrial facilities on Jake Alexander Blvd is not significantly elevated. While there were more suicides than would be expected in Milford Hills, the pattern of these suicides over time does not suggest an environmental association and the small number of suicides makes any statistical findings too unstable to support a geographic pattern. Many risk factors for brain cancers, lymphomas and suicides are known, but environmental risk factors are not well established for these adverse health events. It is not plausible to suggest that environmental factors caused the cancers and suicides when established non-environmental risk factors have not been determined. Exposure to groundwater contamination has been eliminated by the provision of municipal water to Milford Hills residents. Epidemiologic investigations of "cancer clusters" are not fruitful in determining environmental causes of these problems. OEEB does not recommend any further epidemiologic cluster investigation of this issue. It is the opinion of OEEB that appropriate public health measures have been taken to respond to the air and water contaminants in Milford Hills.

Appendix 1:

Health Studies: Cancer

A. Studies by State Center for Health Statistics (SCHS) and Central Cancer Registry (CCR):

1. April 2002, Evaluation of Reported Cluster of Cancer Cases, Salisbury North Carolina, (CCR):

a. County age-adjusted incidence rates for brain cancer for 1990-1999 are not remarkably different from state rates. However, the county rate for 1995-1999 is somewhat higher than the state rate (7.8 cases per 100,000 vs 6.2 per 100,000).

b. Calculations of the expected number of cases for the census tracts surrounding the asphalt distribution terminal revealed that there were actually fewer cases observed than one would expect over the ten years that the Central Cancer Registry has data.

2. April 18, 2002, Memorandum to Leah Devlin from Dale Herman, CCR, Evaluation of Reported Cancer Cluster in Salisbury

Determination of observed cases of brain cancer, multiple myeloma, and leukemia in the census tracts surrounding the asphalt distribution facility compared to the expected number from 1990-1999:

Cancer	Observed	Expected
Brain	10	10.9
Multiple Myeloma	6	9.6
Leukemia	15	17.4

There were fewer cases of all three cancers compared to the number that would be expected.

3. March 2003, Evaluation of Reported Cluster of Cancer Cases, Salisbury NC, (CCR)

a. There were 1.89 times as many cases of brain cancer observed within one mile of the asphalt distribution terminal compared to the number that would be expected. This was not statistically significant.
b. here were fewer total cancer cases, fewer leukemia cases, and fewer lung cancer cases than expected and approximately the same number of cases of lymphoma as expected within a one mile and two mile distance from the asphalt facility.
c. County age-adjusted incidence rates for brain cancer are not remarkably different from state rates.

d. Address information is "soft data." In a highly mobile society the address of a case at any given point in time may or may not be the relevant address as regards etiology. This is compounded by the fact that the latent period of the disease is unknown and is likely not constant between cases.
e. Statistical significance does not imply causality nor does a lack of statistical significance address the issue of biological relevance.

4. June 2004, Cancer Cases Near Asphalt Operations, North Carolina (CCR)

Twelve asphalt operations throughout North Carolina were studied to determine the number of incident cases of brain cancer, lymphoma, and leukemia and compare these to the expected number of incident cases. The study included all incident cases from 1990-2001. All cases identified were reported as residing within census block groups that are within or intersect a two-mile radius of the asphalt distribution terminal. All calculated rates were age-adjusted.

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	236	226.4	1.04	No
Leukemia	337	340.6	0.99	No
Lymphoma	633	624.8	1.01	No

The study concluded that there appears to be no indication of an excess of brain cancer, leukemia, or lymphoma cases within a two-mile distance of the asphalt distribution terminals included in this study.

5. August 2004, Cancer Cases near Asphalt Operations Addendum, Analysis of One-Mile Radius around Asphalt Operations, (CCR)

For the time period 1990-2001, this study determined the number of observed and expected cases of brain cancer, leukemia, and lymphoma in persons residing within a one-mile radius of twelve asphalt operations in North Carolina. This study was done to supplement the study of cases within two miles of the asphalt operations, which is cited in 4. above. The study also revised the previous data for cases residing within two miles of the twelve plants.

Observed and Expected Cases in two mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	236	221.9	1.06	No
Leukemia	337	332.9	1.01	No
Lymphoma	633	611.2	1.04	No

Observed and Expected Cases in one mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	97	93.7	1.04	No
Leukemia	125	141.2	0.89	No
Lymphoma	249	258.5	0.96	No

The study concluded that there appears to be no indication of an excess of brain cancer, leukemia, or lymphoma cases in the study area, regardless of whether the exposed population lives within a distance of one or two miles from the asphalt distribution terminals.

Note: It should be noted that there was a lower observed/expected ratio for all three cancers at the one-mile radius compared to the two-mile radius. If it were postulated that exposure to airborne chemicals from asphalt facilities caused these cancer cases then it would be expected that exposure to greater concentrations of these chemicals would occur at the one mile compared to the two mile radius and there would be a greater number of cancer cases within one mile compared to two miles of the plants. However, the results of this study showed the opposite. There were no statistically significant elevations of rates at either distance from the plants.

6. February 2005, Update of Reported Cluster of Cancer Cases, Salisbury NC (CCR)

The observed and expected numbers of 3 types of cancer were determined for persons reported as residing within a one-mile and a two-mile radius of the asphalt distribution terminal in Salisbury. The expected number of cases was determined by applying age-specific cancer incidence rates for the state to the age-specific populations of the one and two mile study areas. The study period included cases from 1990-2002.

Observed and Expected Cases in two-mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	11	9.6	1.1	No
Leukemia	11	15.8	0.7	No
Lymphoma	31	24.8	1.3	No

Observed and Expected Cases in one-mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	6	2.6	2.3	No
Leukemia	4	4.5	0.9	No
Lymphoma	8	7.0	1.1	No

The report concludes that there appears to be no indication of an excess of brain cancer, leukemia, or lymphoma cases in the study area, regardless of whether the exposed population lives within a distance of one or two miles from the asphalt distribution terminals.

7. April 2006, Update of Reported Cluster of Cancer Cases, Salisbury NC, North Carolina Central Cancer Registry

This is the most recent updated report of the cancer experience in Salisbury produced by the North Carolina State Center for Health Statistics.

The expected number of cases was determined by applying age-specific cancer incidence rates for the state to the age-specific populations of the one and two mile study areas. The study period included cases from 1990-2003.

No new cases were reported for 2003 for the one and two mile radius. It was discovered that four cases reported in the February 2005 report were in fact duplicates of other cases. The duplicates comprised 4 lymphoma cases and were removed from this year's analysis.

Observed and Expected Cases in two-mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	11	10.3	1.0	No
Leukemia	11	17.0	0.6	No
Lymphoma	27	30.6	0.9	No

Observed and Expected Cases in one-mile area of study:

Cancer	Observed	Expected	Observed/Expected	Statistically significant?
Brain	6	2.8	1.8	No
Leukemia	4	4.9	0.8	No
Lymphoma	7	8.6	0.8	No

The report notes that there appears to be no indication of an excess of brain cancer, leukemia, or lymphoma cases in the study area, regardless of whether the exposed population lives within a distance of one or two miles from the asphalt distribution terminals.

Information on the tissue types of cancer:

The following information concerning tissue types of cancers was provided by the CCR:
For cancers within a two mile radius:

- Of the 11 brain cancers, there were 6 different histologic tissue types (6 separate types of brain cancer).
- Of the 27 lymphoma cases there were 14 different histologic tissue types.

For cancers within a one-mile radius:
Of the 6 brain cancers, there were 5 different histologic tissue types.
Of the 7 lymphoma cases, there were 5 different histologic tissue types.

Appendix 1 (cont'd)

B. Study by federal ATSDR:

February 2006, "Review of the Incidence of Cancer Cases among Residents of Rowan County, North Carolina, and Residents Living Near Industrial Facilities in Salisbury, North Carolina," US DHHS, Agency for Toxic Substances and Disease Registry

The numbers of incident cases of twenty general types of cancer were determined for persons residing within a one-mile radius and within two census block groups within the one-mile radius from the asphalt distribution terminal in Salisbury. The expected number of cases for each cancer type was determined by multiplying the Rowan County specific rates by the estimated number of people living within the prescribed area. (The reader should note that the North Carolina CCR used North Carolina state rates to determine the expected number of cases of cancer). Statistical tests were applied to the ratio of observed to expected numbers of cases of each general type of cancer.

The report finds that "...persons living within one mile of the industrial plants near Jake Alexander Boulevard during 1990-2000 did not have a statistically significant higher rate of cancer than 1) other residents of Rowan County, 2) other residents in the state of North Carolina, or 3) people throughout the United States. The residents of census block groups 0513031 and 0513032, however, did have a statistically significant higher rate of lymphoma and brain cancer than did those who live in Rowan County. For the other types of cancers, the rates among the residents of the two census block groups did not differ statistically from the rates in Rowan County as a whole."

The report notes that since there are no individual risk factors known for the cases [because the data are limited to what was reported to the ATSDR by the CCR], this analysis cannot explain why the rates of certain cancers among residents of the two block groups appear elevated. Further, "...the limited overall number of cases and the lack of information about possible risk factors and chemical exposures weaken any observed statistically significant increase." Further, "...a review of cancer registry data is not designed to determine whether exposure to the industrial pollutants may have caused these cancers." The ATSDR concludes that "...ATSDR cannot establish any causal relationship between these elevated rates and any contaminant or condition in the test area."

Appendix 2

Health Studies: Suicide

2003, Suicide and Asphalt Plants, North Carolina, SCHS

This report evaluated the number of suicides in persons living within a two-mile radius of eleven asphalt distribution terminals for the entire state of North Carolina. The rate per 100,000 persons was calculated for persons living within two miles of eleven asphalt distribution terminals ("exposed") and compared this to the rate for persons in the rest of the state of North Carolina ("Control").

Group	Number of suicides	Population (2000 census)	Rate per 100,000
Exposed	21	81,404	8.6
Control	2,537	7,997,907	10.6

The rate for persons "exposed" to asphalt plants was lower than the rate for persons "not exposed" suggesting that living within two miles of an asphalt distribution terminal is not a risk factor for suicide.

When the rates for each plant location were determined, the rates ranged from 0 to 32.7, with Rowan County having 32.7 per 100,000. When two census blocks closest to the asphalt distribution terminal on Jake Alexander Blvd were evaluated, six suicides were found. Statistical tests were used to determine if the rates of the census blocks were statistically significantly different from the state rate. One test (the "difference of means test") found no difference. The odds ratio for the period was 3.25 with a confidence interval ranging from 1.45 to 7.23 was found, making the odds ratio statistically significantly elevated. However, due to small numbers (six suicides in ten years), "it is difficult to establish stable statistical relationships." It must be remembered that statistical significance does not imply causality.

In Rowan County there were the following number of suicides for each year between 1994 and 2003:

1994 - 1
1995 - 2
1996 - 0
1997 - 0
1998 - 0
1999 - 0
2000 - 0
2001 - 1
2002 - 0
2003 - 2

The report notes that during the time period before 2002, before any activated carbon filters were placed on the tanks and when asphalt emissions were high, there were no suicides from 1996 through 2000. There were 2 suicides in 2003, after activated carbon filters had been installed and emissions of hydrogen sulfide had been noticeably decreased. Further, "the bimodal distribution of the incident suicide cases suggests that there is little relationship to the level of emissions from asphalt processing." The report notes that causative linkages between hydrogen sulfide and mood depression have not been clearly established in human trials, and "other factors" may explain the clustering of suicides in 1994-1995 and 2001-2003. It further notes: "At this point and with this data, it is near impossible to establish a relationship between suicides and chemical emissions from the plant."

Appendix 3

Environmental Studies

The following are results of environmental studies performed by DENR of the air in the immediate vicinity of the asphalt distribution terminal and in the Milford Hills area. This investigation occurred from May through September 2001:

August 29, 2003, Division of Air Quality Toxics Protection Branch, Air Toxics Analytical Support Team (ATAST) Salisbury Air Quality Monitoring Study, Final Study Report

1- Hydrogen Sulfide (H2S) is the most emissive toxic compound identified to be emitted from the Associated Asphalt liquid asphalt terminal and appears to be emitted at significant levels from hot mix asphalt distribution terminals.

2- H2S emission control practice at many liquid asphalt terminals is non-existent.

3- Monitoring data, process data, citizen complaints, and dispersion modeling argue strongly that the liquid asphalt terminal is the primary contributor to the H2S levels above the odor threshold in the nearby area.

The greatest levels of H2S occurred at the asphalt distribution terminal site but diminished rapidly off-site. Measured levels at a cul-de-sac in Milford Hills located 200 meters from the asphalt distribution terminal were above odor threshold (8 ppb) four times in four months but did not approach odor nuisance levels (40 ppb).

4- Monitoring data and dispersion modeling show that ambient concentrations of benzene and other VOC's in Salisbury are typical of air in similar areas and communities.

   The report notes that while benzene levels were elevated at the asphalt distribution terminal site, levels in the nearby community were similar to urban settings in North Carolina and neighboring states. For example, the study indicated that the average 24-hour benzene concentration for Milford Hills was 0.16 ppb, within the range of 0.13-0.24 ppb measured in other suburban and rural sites in and around North Carolina during 24-hour periods. DAQ concludes that in terms of ambient air quality, the concentrations [of VOC's] measured in the Salisbury study indicate that the air in this area is typical of air in other similar areas.

Hydrogen Sulfide detected in ambient air in Salisbury- Concentration range is listed in parts per billion (ppb): May-September 2001

Number of 1-hour hydrogen sulfide Concentration Measurements (ppb)

Location	< 1.25	1.25-10	10-30	30-50
Access road site (30 m from Assoc Asphalt)	1825	717	25	3
Cul de sac site (200 m from Assoc Asphalt)	2185	120	4	0
Remediation site (400 m from Assoc Asphalt)	2795	13	0	0

The odor threshold for hydrogen sulfide is from 1-8 ppb. Most measured levels of hydrogen sulfide in and around Milford Hills were less than 1.25 ppb. The "nuisance level" for hydrogen sulfide is 40 ppb. The above table shows that all but three samples were less than the nuisance level.

Volatile Organic Compounds (VOC's) detected in ambient air in Salisbury; samples were taken from May through September 2001; concentrations are 24-hour averages and are listed in "parts per billion" (ppb). These samples were collected at a "Cul de Sac" road in Milford Hills and an Access Road adjacent to Milford Hills.
For comparison purposes, the table lists concentrations of the same VOC's which have been measured at rural sites in Douglas, Georgia and Dawsonville, Georgia:

Chemical:	Milford Hills Concentration:	Dawsonville GA Concentration	Douglas, GA Concentration
Benzene	0.16	0.13	0.23
1,2 dichloroethane	0.13	0.13	0.13
Dichloromethane	0.12	0.20	0.24
1,2 dichloropropane	0.13	0.13	0.13
Ethyl chloride	0.21	0.13	0.13
Ethyl benzene	0.13	0.13	0.56
Methyl chloride	0.48	0.64	0.73
Styrene	0.13	0.13	0.13
Toluene	0.42	0.13	1.71
m,p-xylene	0.14	0.13	2.01
o-xylene	0.13	0.13	0.50

Groundwater evaluation:

March 18, 2003: Memorandum from Mooresville Regional Office, Division of Water Quality, Groundwater Section:

Findings:

Groundwater flow is from the industrial facilities on Jake Alexander Blvd away from the Milford Hills neighborhood.

While there has been contamination of the groundwater at the industrial facilities on Jake Alexander Blvd, this has not caused contamination of the Milford Hills neighborhood.

The direction of groundwater flow is generally from the asphalt facility towards the southeast and south-south east, away from the Milford Hills area. The report notes that the [Milford Hills] neighborhood is hydraulically up- or cross-gradient from the asphalt facility. Concentrations of petroleum products in groundwater decrease in the direction of the neighborhood. The report states that groundwater contamination from the asphalt facility is "...clearly not moving towards the [Milford Hills] neighborhood based on the available data."

Retrospective water modeling has too many uncertainties, can lead to very different results based on different assumptions that might be made, and is not recommended.

Two types of contaminants have impacted groundwater in the vicinity of the Milford Hills neighborhood: petroleum products and chlorinated solvents.

Petroleum issues:
Petroleum discharges at the former Exxon Terminal and the Southern States Cooperative have impacted groundwater. The extent of contamination for each site has been determined and both sites are in corrective action. Petroleum discharges at the former Exxon Terminal and the Southern States Cooperative sites do not impact groundwater in the Milford Hills neighborhood.

Chlorinated solvent-related issues:
Chlorinated solvents have been detected in water supply wells in the Milford Hills neighborhood. Residences formerly served by these wells are currently served by the municipal water system. Other wells in the vicinity are still in use. These wells are being sampled regularly by the Mooresville Regional Office Groundwater Section to ensure that well owners are not at risk. Contaminants found at the NCDOT Asphalt Testing site and the former Chevron Sites include Trichloroethylene (TCE) [but this was not found in Milford Hills].
The contamination of the former NCDOT asphalt-testing site appears to be unrelated to the identified contamination in the Milford Hills neighborhood.

Chemicals detected in wells (groundwater) between 1992 and 2005 in sites on Jake Alexander Blvd (JAB) and from private residences in Milford Hills. Concentrations listed are the highest concentration found for that site. Concentration is expressed as ppb (parts per billion).

Date	Location	Chemical	Concentration	Standard
	Jake Alexander Blvd			
		Chloroform	1.6	0.19
12/23/01		1,2 dichloroethane	1.7	0.38
1/23/01		1,1 dichloroethane	0.47	
		1,1 dichloroethene	136.0	7.0
		1,2,dichloroethene	1.7	
		Tetrachloroethene	0.7	0.7
		1,1,1 trichloroethane	29.9	200
		Trichloroethene	0.9	2.8
	Milford Hills neighborhood:			
	Dan Street	Chloroform	1.1	0.19
11/8/01		Carbon tetrachloride	0.32	
1/21/93	Spring Drive	Tetrachloroethene	5.3	0.7

Risk of carcinogenicity of airborne chemicals at concentrations found in and adjacent to Milford Hills subdivision:

Chemical:	Risk of carcinogenicity at Highest concentration found?	Risk of brain cancer or lymphoma in humans at highest concentration found?
Benzene	Animals: very low risk leukemia	No
1,2 dichloroethane	Animals: very low risk hemangiosarcoma	No
1,2 dichloropropane	Animals: very low risk liver, mammary gland	No
Ethyl benzene	Animals: very low risk kidney, testes, liver, lung	No
Ethyl chloride	Animals: very low risk skin	No
Hydrogen sulfide	No	No
Methyl chloride	Animals: very low risk Kidney	No
Styrene	Animals: very low risk: Lung, mammary gland	No
Toluene	No	No
m,p-xylene	No	No

Risk of Carcinogenicity of waterborne chemicals found at Jake Alexander Blvd and in Milford Hills Subdivision:

Chemical:	Risk of carcinogenicity at Highest concentration found?	Risk of brain cancer or lymphoma in humans at highest concentration found?
Jake Alexander Blvd only:		
Chloroform	No	No
1,1 dichloroethane	Very low risk: animals: hemangiosarcoma	No
1,2 dichloroethane	Very low risk: animals: hemangiosarcoma Risk less than 1 out of 100,000	No
1,1,1 trichloroethane	No	No
Tetrachloroethylene	Very low risk: Animals: liver Risk: 1out of 1 million	No
Trichloroethylene (Trichloroethene)	Low risk: Animals: liver and kidney	Not adequate data
Milford Hills:		
Chloroform	No	No
Carbon tetrachloride	Low risk: Animals: liver	No
Tetrachloroethylene	Very low risk: Animals: liver Risk: 1out of 1 million	No

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), Evaluation of Neurobehavioral Health Status for Chronic and Repeated Exposure to Hydrogen Sulfide, Dakota and South Sioux Cities, Nebraska, Final Report, February 2003.

Agency for Toxic Substances and Disease Registry (ATSDR), Review of the Incidence of Cancer Cases among Residents of Rowan County, North Carolina, and Residents Living Near Industrial Facilities in Salisbury, North Carolina, February 2006, 1-14.

Armitage JO, Longo DL, "Malignancies of Lymphoid Cells," in Harrison's Principles of Internal Medicine, 16th ed, eds. Kasper DL, Braunwald E et al, McGraw Hill, 2005, 641-55.

Caldwell GG, Twenty-two years of Cancer Cluster Investigations at the Centers for Disease Control, American Journal of Epidemiology, 1990, 132, supplement No. 1, S43-S47.

Campbell DS, Smith CG, "Cancer Clusters," in Environmental Health Secrets, Hanley & Belfus, 2001, 110-115.

Eyer P, "Gases," in Toxicology, Marquardt H, Schafer SG, McClellan RO, Welsch F, eds, Academic Press, 1999, 805-32.

Hill AB, The Environment and Disease: Association or Causation, Proc R Soc Med, 1965; 58: 295-300.

Marquardt H, "Chemical Carcinogenesis" in Toxicology, Marquardt H, Schafer SG , McClellan RO, Welsch F, eds., Academic Press, 1999, 151-78.

NCI, Probability of Developing or Dying of Cancer Software, Version 5.1, Statistical Research and Applications Branch, NCI, 2003. http:srab.cancer.gov/devcan.

Rothman KJ, A Sobering Start for the Cluster Buster's Conference, American Journal of Epidemiology, 1990, 132 supplement 1, S6-S13.

Rothman KJ, Greenland S, "Causation and Causal Inference" in: Modern Epidemiology, 2nd Ed., Rothman KJ and Greenland S eds, Lippincott Williams & Wilkins, 1998, 7-28.

Sagar SM, Israel MA, "Primary and Metastatic Tumors of the Nervous System," in Harrison's Principles of Internal Medicine, 16th ed, eds. Kasper DL, Braunwald E et al, McGraw Hill, 2005, 2452-61.

US DHHS, PHS, Toxicological Profile for Hydrogen Sulfide, July 1999
US EPA, Integrated Risk Information System, http://www.epa.gov/iris/subst/.